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DETERMINATION OF TIMELINESS COST USING METHOD OF AVERAGE WORKABILITY ROBABILITY BASED ON RELIABILITY FUNCTION OF FARM TRACTORS

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Abstract

There is an optimum time for implementing field operation of a crop in each region. If the operation were accomplished sooner or later, it might cause a reduction in yield quantity and quality that is named *timeliness cost*. The purpose of this study is to survey the timeliness cost of harvesting operation of sugar cane based on reliability function of MF285 tractors operating in Debal Khazaei Agro-Industry Co. in Khuzestan, a province of Iran. MF285 tractors have low reliability in Iran, and due to their low reliability have an uncertainty in implementation of farm operation, though it is not considered in ASAE equation for calculating of timelines cost. This uncertainty causes cost which is a part of timeliness cost and is produced due to tractor failure during farm operation. Thus, the reliability function of tractors based on distribution fitting of tractor operation times to a failure is obtained. Then, other timeliness factors in the formula are determined according to the study conditions. At last, tractor timeliness cost of harvesting operation caused by MF285 tractors is calculated using new modified equation and after that, its relation with farm tractor mission time (t_m) is determined. Results showed that timeliness cost increased whatever machine mission time increased way that intensity of increase in lower mission times was less than upper ones.

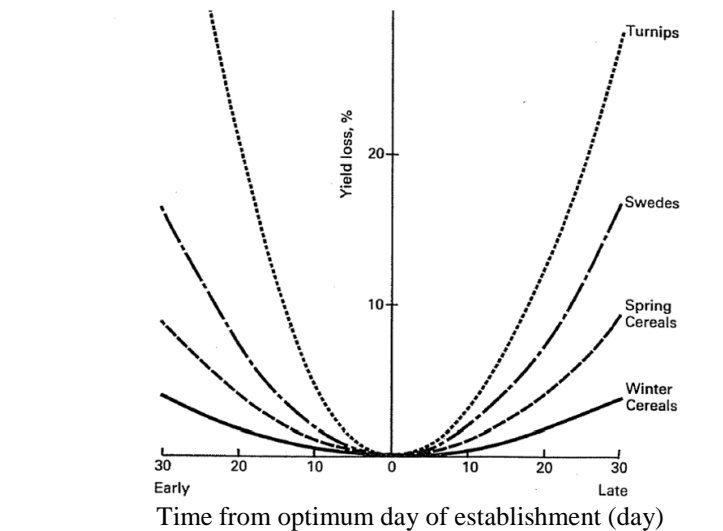
Keywords: ASAE Equation, Farm management, Optimum Time, MF285, mission time

Abbreviations used: TC (Timeliness Cost); MF285 (Massy Ferguson Model 285); A.W.P (Average Workability Probability); DWS (daily work status method); TC_{Tr} (timeliness cost of harvesting operation caused by MF285 tractors); MTTR (mean time to repair); t_{max} (tractor maximum mission time)

1. INTRODUCTION

When a field operation is performed, there is normally an optimal time for this operation with respect to the value of the crop. If the operation were performed earlier or later, the value of the crop could decrease due to the changes in quantity or quality (Fig. 1) (Anonymous, 2006b). The economic consequences of performing a field operation at non-optimal time are called *timeliness costs*. If an operation is done after the optimal time, timeliness costs occur on the whole area before the operation is started and thereafter on a decreasing area depending on the capacity of the operation. Since these costs are partly dependent on planning and scheduling of

the field operation and on machine capacity, they are also referred to as *indirect machine costs*. Timeliness costs are important to be considered for efficient crop management and machinery selection, particularly for crop establishment, spraying, harvesting and soil compaction (Witney, 1995; Chapman *et al.*, 2008; Gunnarsson, 2008). Significant timeliness costs can be occurred in regions with short periods available for sowing and harvesting and since they are affected by the weather, such costs are specific for the regions and are subjected to annual variations (Toro A., 2004; Gunnarsson, 2008, García *et al.*, 2015).



Picture 1. If the operation were accomplished sooner or later, it might cause a reduction in yield quantity and quality which is shown in the figure as “yield loss”. Percentage yield losses from untimely crop establishment that varies for each crop in a region. (Witney, 1988).

Generally, three reasons cause to timeliness: reduction of machines reliability, inaccurate and non-optimum schedule and false prediction of needed machines. If tractor reliability is low, however, field scheduling is optimum and needed machines for field operation is predicted correctly, because of field failures, field operation would be failed and a part of scheduled times would be wasted (Almasi *et al.*, 2008). Evaluation of this penalty costs requires the selection of a unique yield/time response for a multiplicity of crop yield experiments (witeny, 1985).

Wetzstein *et al.* (1990) investigated the importance of timeliness in selection of machinery complements for a double-crop wheat and soybean production in the southeastern coastal plain. Existing survey information indicated that six-row equipments are representative of the production system. The results of their study showed that proper selection of machine and its reliability are very important in optimum usage of soil moisture, timeliness and dependant cost reduction. Schneeberger and Bar (1997) investigated the effect of harvesting period of three varieties of sugar beet B, C₁ and C₂ on timeliness cost. They obtained harvesting period information of sugar beet fields and calculated timeliness cost for the mentioned varieties. They concluded that the optimum harvesting period of B variety is 41 days and for both C₁ and C₂ are 45 days. Toro and Hansson (2004) developed a simulation model for field machinery operations using a discrete event simulation technique in order to analyze machinery performance based on daily status of soil workability for a series of years (Daily Work Status method), and then compared the results

with those obtained from a simpler method based on average probability values of available workdays for operations and seasons (Average Workability Probability method). They showed that the Average Workability Probability method (A.W.P.) estimates lower timeliness costs for sowing operations than those determined with the Daily Work Status method (D.W.S.), which was attributed to the fact that former method did not take into account chain effects. Toro (2005) analyzed the influence of daily weather on timeliness costs of field machinery on cereal farms in Sweden while varying their size, number of drivers, farm sizes and their location. He linked a discrete event simulation model with a soil model to simulate daily field operations of a farm for a series of years to infer daily soil workability. He utilized completion dates of operations for individual fields and years to quantify annual timeliness costs in details for 15 or 20 years. He calculated the timeliness cost using the following equation;

$$Y_l = P_d A_f (D_s - D_o) + 0.5 P_d A_f (D_f - D_s) \quad (2)$$

where: Y_l is the annual yield losses in kg for each field for sowing or harvesting operations; P_d is the daily penalty in kg.day⁻¹.ha⁻¹; A_f is field area in ha; D_s is the start day for operation as a day number; D_o is the optimum day for operation as a day number; and D_f is the finishing day for operation as a day number. In cases where $D_f < D_o$, a value equal to 0 was assigned to yield losses Y_l . In other cases, where the differences $D_s < D_o$ and $D_f > D_o$, he assigned D_s the same value of D_o . This latter assignment introduced a small error into timeliness cost estimations for the autumn sowing

operation in some cases. Spring sowing and harvesting operations always started on the 'optimum day number' or later. Pishbin *et al.* (2008) investigated timeliness cost of plowing, fertilizing, land leveling and planting operations in 227 sugar beet farms in Eghlid, Marvdasht and Fasa¹ using AWP method. They determined timeliness cost of these operations as 12237, 3147 and 2622 Rials.ha⁻¹ respectively. Also, they obtained the timeliness cost of the second fertilizing, spraying and cultivating operations per one day delay in sugar beet farming equal to 881, 1101 and 3671 Rials.ha⁻¹ respectively.

Tractor is one of the most determinant implement in on time accomplishment of field operation (Girard and Hubert, 1999). Farm tractors failure, especially during the engaged part of the season, causes delays which result in losses and inefficient labor utilization (Amjad and Chaudhary, 1988). The timeliness cost and losses from delay in farm operation haven't been considered seriously in Iran yet. Therefore, financial losses due to machine reliability, decrease and subsequently, continual machine failures and farm breakdowns, aren't included by Iranian farmers (Ashtiani *et al.*, 2006). The aim of current research is to determine timeliness cost using average workability probability method based on reliability function of MF285 tractors operating in Debal Khazayi Agro-Industry Co. Thus, the timeliness cost of farm tractors that is a variable tractor cost, is calculated.

2. MATERIALS AND METHODS

Synopsis

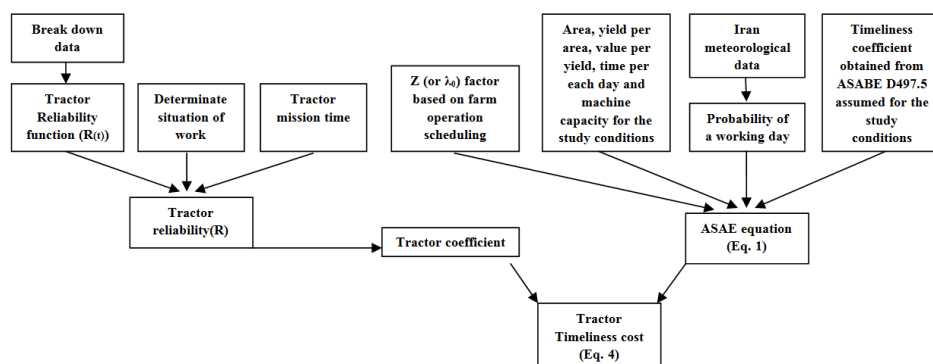
1. Three cities in Fars province of Iran

Timeliness cost is calculated using the formula for an operation proposed by ASAE in Standard EP496.3 (Anonymous, 2006a):

$$W = \frac{A.Y.V.K_3}{Z.C_i.P_{wd}.G} \quad (1)$$

Where: W is annual timeliness cost for the operation involved, (\$); K₃ is timeliness coefficient obtained from ASAE Standard D497.5; A is crop area involved, (ha); Y is yield per area, (t/ha); V is value per yield, (dollars/ton); Z is 4 if the operation can be balanced evenly about the optimum time (balanced scheduling), and is 2 for premature or delayed schedules; G is expected time available for field work each day, (h); C_i is machine capacity, (ha/h) and P_{wd} is probability of a working day, (decimal). In a study developed by Toro and Hansson (2004), application of above equation was called *Average Workability probability* method.

For estimating timeliness cost, all timeliness factors utilized in ASAE formula should be calculated. Additionally, in order to determine the effect of low reliability of farm tractors on timeliness losses, the reliability function of MF285 tractors available in Debal Khazaie Agro-Industry Co. was obtained. Therefore, the timeliness cost of tractors was assessed in the following way (the procedure is also outlined in Fig. 2):



Picture 2. Schematic representation of the approaches for estimating tractor timeliness costs based on tractors reliability.

1. In order to develop the reliability function, tractors operation times to a failure were calculated with field operation. Afterwards, the best distribution function for failure data was determined and the reliability function was obtained for tenth year of tractors life.

2. Tractor mission times were assumed based on the machine capacity and field operation that in which MF285 tractors are used. Tractor operators, maintenance unit and operating conditions for all MF285 tractors were the same. Thus, tractor reliability was calculated at the defined situations.

3. Z (or λ_0) factor was determined based on the farm operation scheduling of sugar cane harvesting.

4. Probability of a working day was determined using data from Ahvaz¹

station of Iran meteorological organization.

5. Timeliness coefficient of the formula was obtained from ASAE Standard D497.5. This factor is assumed based on the climate conditions of the study area and harvesting of the sugar cane.

6. Area, yield per area, value per yield, time per each day and machine capacity for the study conditions were determined.

7. Finally, the effect of tractor reliability on timeliness cost was indicated as (probability of failure)*(Average downtime)/(tractor maximum mission time) and was named *tractor coefficient*. Therefore, Equation 4 was developed to calculate the tractor timeliness cost using average workability probability method based on reliability function of MF285 tractors.

8.

2. A city located in 25 kilometers northeast from Debal Khazaie Agro-Industry Co.

Study area

Debal Khazaei Agro-Industry Co. is located in 25 kilometers south of Ahvaz in Iran. Arable lands of this company are located in 31° to $31^{\circ}10'S$ latitude and 45° to $48^{\circ}36'E$ longitude. This region has dry and warm climate. Soil of this region is heavy and semi-heavy and each farm size is 25 ha in regular forms. Totally, 65 MF285 tractors, 20 MF399 tractors and 15 MF8160 tractors are used in this company.

Timeliness factors

Determination of the reliability function of MF285 tractors

Many of quantitative factors which are used in machine maintenance topics are based on principles of statistics and distribution functions. Among these factors, the probability of healthy and well function of machine is very important. If the machine working conditions and failure data would be available, it is possible to estimate machine performance in the future. Thus, in Debal Khazaei Agro-Industry Co. the reliability function was determined in tenth year of tractors life. The reliability function was determined based on analytical method. Farm tractor was assumed a mission oriented system against continuously operated system. Mission oriented systems must have healthy and well function without any failure within mission time (t). Thus, farm tractors were assumed as a non-repairable system. Non-repairable systems are those that do not get repaired when they fail. Specifically, the components of the system are not repaired or replaced when they fail.

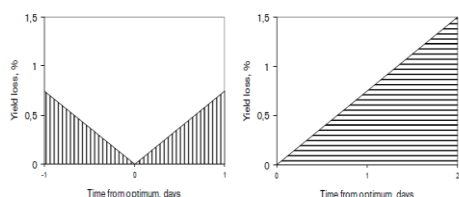
A function-fit model for reliability of farm tractors was determined. This model intended to capture the effect of tractor failures in timeliness of farm operation. Thus, tractors entree and exit from maintenance unit of the company were recorded in tenth year of tractors life. Working hours of tractors from a failure to next one, were determined. Then, in order to develop the age distribution function, first, the parameters of functions were estimated using moments method in software XLSTAT 2014. After that, distribution fitting test of these working hours using MATLAB software version 8.4 (R2014b) based on Chi-square test was carried out. Mainly, age distribution functions are considered as normal, exponential, log-normal, poisson and weibull. Generally, each machine follows its age distribution function and reliability based on working conditions, quality of parts combination, manufacturing process and many other ingredients (Billinton and Allan, 1992).

Tractor mission time (t_m) and situation of work

Midwestern US reports by farmers of field failures showed the probability of failure (combination of tractors and their implements) per 40 ha of use (Anonymous, 2006b). Therefore, tractor mission in ASAE standard D497.5 is equal to 40 ha operation of both tractors and implements. While in this study, maximum mission time (t_{max}) was assumed as 125 hours of tractor operation. Indeed, 125 hours of operation, is 50 ha of use with 0.4 ha/h field capacity.

Determination of Z (or λ_0) factor

Based on the ASAE Standard EP496.3, the Z (or λ_0) factor is assumed as 4 if the operation can be balanced evenly about the optimum time, and a value of 2 if the operation either commences or terminates at the optimum time (Anonymous, 2006a). When planning an operation, two alternatives are available for starting point, referred to as balanced and delayed scheduling, illustrated in Fig. 3. By starting the operation before the optimum time, timeliness losses can be reduced compared to the losses at delayed scheduling (see the marked area in Fig. 3).



Picture 3. Illustration of balanced (left) and delayed (right) schedule; By starting the operation before the optimum time, timeliness losses can be reduced compared with the losses at delayed scheduling (Gunnarsson, 2008)

Delay in harvesting sugar cane and reaching the crop to high temperatures cause the Sucrose to be converted to Glucose and Fructose and subsequently reduces the percent of sugar extraction. On the other hand, rainfalls from November begin and this creates many problems in harvest scheduling, farm management and manufacturing of Agro-industry Company. In order to prevent such problems, the Company applies the premature scheduling on sugar cane

harvest. Thus, Z (or λ_0) factor for harvest operation was assumed as 2 for harvest operation. For most harvesting operations, it is not feasible to begin harvesting until the crop is mature (Srivastava *et al.*, 2006).

Estimation of probability of a working day

Sugar cane is harvested from November to April. Climate conditions data in this period (NOV. to APR.) were obtained from Ahvaz station of Iran meteorological organization. This data is shown in table (1);

Table 1. Number of clear, partly cloudy and cloudy days in Ahvaz averagely from 1951 to 2005 (Anonymous, 2005)

Month	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	Total
Clear days	17.6	14.3	15.1	15.5	16	15.5	94
Partly cloudy days	8.2	9.5	8.1	7.7	8.5	9.4	51.4
Cloudy days	4.2	6.2	6.8	6.8	5.5	5.1	34.6

Delay in harvesting is resulted in the coincidence of the crop harvesting with high temperature and subsequently causes to convert Sucarose to Glucose and Fructose and consequently it causes in decreasing the percent of sugar extraction from cane (Khajehpour, 1998). On the other hand, rainfalls begin from November and this creates many problems in harvest scheduling, farm management and sugar manufacturing in

Agro-industry Company. Probability of a working day for sugar cane harvesting operation was estimated using the following equation. This method was described in details by Pishbin *et al.* (2008);

$$P_{wd} = \frac{1/8 \text{ Cloudy days} + 1/2 \text{ Partly cloudy days} + \text{Clear days}}{\text{whole days in harvesting period}} \quad (3)$$

Timeliness coefficient (k)

The most appropriate timeliness coefficient for sugarcane harvesting operation has been reported only in ASAE D497.5. K value, derived from crop research reported for sugarcane in Queensland of Australia, is 0.002 for premature scheduling and 0.003 for delay scheduling. Queensland of Australia is located at 29°S latitude and 138°E longitude. This region has low rainfall and hot summers like Ahvaz (Anonymous, 2010). Therefore, k factor in this case was assumed as 0.002 for

sugarcane premature harvesting operation.

Adjustment of the other timeliness factors for harvesting operation of sugar cane

The area where a tractor works per a year is about 50 ha. Yields per area were obtained averagely from 7 years yields of sugar cane harvesting are shown in table 2.

Table 2.Total area and yield per area of sugar cane in the company farms

Farming Year	Total area(ha)	Yield per area	Total yield (ton)
2000-2001	1848	90	165485
2001-2002	3361	101	338161
2002-2003	4989	93	465531
2003-2004	6439	83	536046
2004-2005	7249	71	515399
2005-2006	7089	78	555939
2006-2007	8243	70	580660

Value per yield was 100 Rials (Iranian Currency) based on 2010 values. Expected time available for field work each day was assumed as 24 hour because tractor maximum mission time ($t_{\max}=125$ h) is more than whole hours of a day (24 h). Mean time to repair (MTTR) or average downtime was 24h and also farm tractor schedule was assumed *mission oriented* system against *continuously operated* system.

3. Results

Modifying ASAE formula

$$TC_{Tr} = (Tractor.Coefficient) \frac{A.Y.V.K_t}{\lambda_0.C_e.P_{wd}.T}$$

$$Tractor.Coefficient = F(t) \frac{MTTR}{t_{\max}} \quad (4)$$

$$F(t) = 1 - R(t)$$

Where: F(t) is tractor failure probability for determination of mission time on harvest operation (sometimes called unreliability, or the cumulative probability of failure), (decimal); TC_{Tr} is

Low tractor reliability has an uncertainty in implementation of harvesting operation and this uncertainty has cost. This cost is a part of total timeliness cost reported in ASABE EP496.3. The mentioned cost does not include the timeliness cost of tractors low reliability by. Therefore in this study, effect of tractor low reliability on timeliness cost is indicated as $F(t)*(MTTR)/(t_{\max})$ and is named as *tractor coefficient*. Thus, Eq. 4 is developed to survey tractor timeliness cost in average workability probability method based on reliability function of MF285 tractors;

tractor timeliness cost for the operation involved, (Rial¹); MTTR is mean time to

¹. Rial; is the currency of Iran, 10,000 Rials = 1 US Dollar

repair, (h); t_{\max} is tractor maximum mission time, (h); A is crop area involved, (ha); Y is yield per area, (ton/ha); V is value per yield, K_t is timeliness coefficient obtained from ASAE D497; (R/ton); λ_0 is 4 if the operation can be balanced evenly about the optimum time (balanced scheduling), and 2 for premature or delayed or premature schedules; C_e is machine capacity, (ha/h); P_{wd} is probability of a working day, (decimal) and T is an expected time available for field work per day, (h/day).

This equation is almost the same as ASAE equation (Eq. 1) however the difference is that this cost is only tractor

timeliness cost. Tractor costs are divided into two categories, fixed costs and variable costs. Timeliness cost is a variable cost that based on Eq. (4) increases with tractor reliability decreasing.

Timeliness factors

According to the study assumptions, results of calculating timeliness factors are shown in table (3). The table 3 shows fixed parameters in this investigation.

Table 3. Timeliness cost factors estimated based on study assumptions

Factor	A	Y	V	K_t	λ_0	C_e	P_{wd}	T
Unit	(ha)	(ton/ha)	(R/ton)	(day ⁻¹)	-	(ha/h)	-	(h/day)
Quantity	50	84	10 ⁶	0/002	2	4.0	69.0	24

Tractor reliability function and goodness of fitting

The best model for age distribution function of MF285 tractors is exponential function (Eq. 5). Reliability function corresponding to table 4 was exponential distribution function as shown in Eq. 6;

$$f(t)=0.025e^{-0.025t} \quad (5)$$

$$R(t)=e^{-0.025t} \quad (6)$$

Tractor operation times to a failure have been grouped in 10 classes which are shown in table 4. This grouping is based on Chi-square test that must be no more than 20% of all expected frequencies in classes with less than 5% frequencies. Also, comparison between the observed and theoretical frequencies for these operating times is shown in table 4.

Table 4. Comparison between the observed and theoretical frequencies

Expected Frequency in Distribution				Observed Frequency	Upper bound	Lower bound	class
Weibull	log- normal	exponential	normal				
18.7	19.3	31.7	10.7	25	13	0	1
27.5	31.6	22.8	15.7	26	26	13	2
21.6	21.4	16.4	19	14	39	26	3
15.5	13.4	11.8	19.1	15	52	39	4
10.6	8.4	8.5	16	8	65	52	5
7.1	5.5	6.1	11	12	78	65	6
4.6	3.7	4.4	6.3	6	91	78	7
2.9	2.5	3.2	3	2	104	91	8
1.8	1.8	2.3	1.2	3	117	104	9
1.1	1.3	1.6	0.4	2	130	117	10

As shown in table 5, based on Chi-square test for normal, log-normal, poisson and weibull distribution as the computed P-values are lower than the significance level $\alpha=0.05$, one should reject the null hypothesis H_0 , and accept the alternative hypothesis H_1 . Therefore, with 95% confidence, normal, log-normal, poisson and weibull distribution are different from observed data. The risk to reject the null hypothesis H_0 while it is true in normal, log-normal, poisson and weibull distributions are respectively lower than 0%, 2.4%, 0% and 4.3%. The exponential distribution as the computed p-value is greater than the significance level $\alpha=0.05$, one should accept the null hypothesis H_0 . Therefore, in 5% level, it couldn't be rejected that the sample follows the exponential distribution function and this distribution has good adaptation with the observed

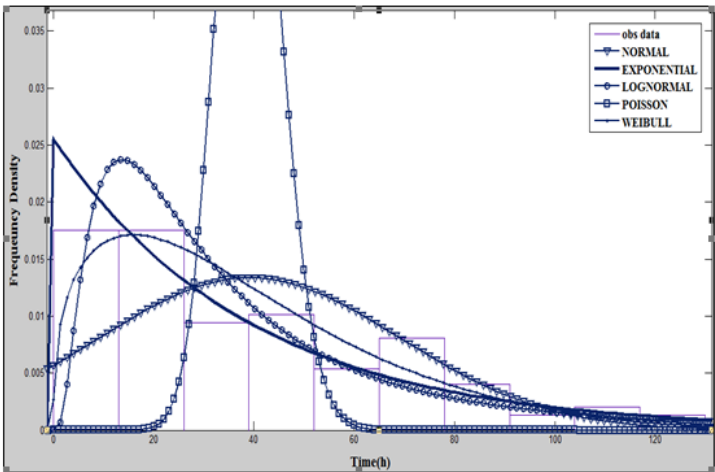
data. Yet, the estimated parameters from distribution fitting are given in table 5.

Table 5. Chi-square test and estimated parameters for distribution functions

Distribution functions	χ^2	$\chi^2(\alpha, df)$	Df	P-value	Estimated Parameter				
	(Observed value)	(Critical value)			μ	σ	λ	β	θ
Normal	42.1	14.1	7	0	39.4	29.8	-	-	-
Exponential	10.1	15.5	8	0.255	-	-	0.025	-	-
Log-normal	16.1	14.1	7	0.024	3.4	0.8	-	-	-
Poisson	432781	12.6	8	0	-	-	39.4	-	-
Weibull	14.5	14.1	7	0.043	-	-	-	1.34	38.6

Density distribution functions versus observed data (histogram) as intuitive in

Fig. 4 show that exponential function has a good fitness with observed data.



Picture 4. Density distribution functions and observed data

Density distribution functions versus observed data (histogram) as intuitive show that exponential function has a good fitness with observed data but other distribution functions has not.

Relation between tractor mission time and timeliness cost

With reliability variation, the tractor timeliness cost changes as it is shown in table 6. Actually, this variation is based on tractor mission time (t) in different amounts. Fundamentally, reliability is varying from 0 to 1 but in this study, reliability of tractors changes from 0.5 to 1 because; tractor mission time is lower than 24 h in practice. Generally, after a day (24 h) work without a failure,

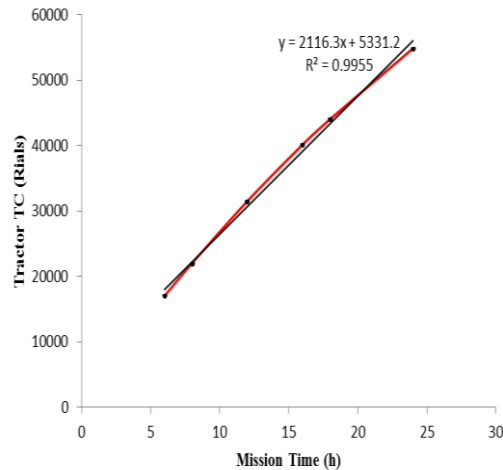
machine is serviced and the day after, the machine is given a new mission time.

Table 6. Timeliness cost in average workability probability method based on reliability

Tractor mission time	Tractor reliability	Probability of a failure during mission time	Tractor coefficient	tractor timeliness cost
$t(h)$	$R(t)$	$1-R$	$F(t) \frac{MTTR}{t_{max}}$	$TC(R/ha)$
6	0.860	0.140	0.02688	17043.47
8	0.819	0.181	0.03475	22034.78
12	0.741	0.259	0.04972	31530.43
16	0.670	0.330	0.06336	40173.91
18	0.638	0.362	0.06950	44069.57
24	0.549	0.451	0.08659	54904.35

If tractor mission time is 6 based on reliability function of tractors at tenth year of their life, tractor reliability will be 0.86. In other words, if tractor is serviced each 6 hours and then is given a new mission again, the probability of tractor healthy and well function will be 0.86 for this time and determinate situation of harvesting operation in the company. Results indicated that increase in the probability of a failure during

mission time has a substantial effect on tractor timeliness cost. With increasing mission time, the tractor timeliness cost is also increasing. This increase in intensity was lesser in low mission times. As shown in Fig. 5, in lower mission times, diagram is gentler inclined and t varying had lesser effect on tractor timeliness cost.



Picture 5. tractor timeliness cost variation vs tractor mission time increase

Discussion

Field efficiency is the ratio between the productivity of a machine at field conditions and theoretical maximum productivity. Field efficiency accounts for failure to utilize the theoretical operating width of the machine; time lost because of operator capability, habits and operating policy; and finally field characteristics. Travel to and from a field, major repairs, preventive maintenance, and daily service activities are not included in field time or field efficiency.

In working conditions of the most Agro-Industries, as a machine fails during farm operation, the stopping machine is immediately replaced with a supporter (spare) machine. But in the individual farms without technical services, the machine does not have a spare in farm and as it fails, operation stops and is postponed to another time. The newest tractors have higher reliability and lower probability of failure during a farm

operation. Thus, one of the most important advantages of old tractor replacement with the new one is on time completion of farm operation. This means that the newest tractors have lower timeliness cost.

Conclusion

In this study, the timeliness cost which is created because of low tractor reliability was captured. This cost is named *tractor timeliness cost*. Tractor timeliness cost was calculated for sugar cane harvesting operation using *average workability probability* method. Really, this method uses ASAE formula (Eq. 1). However, this method does not include tractor reliability effects and delays in operation caused by tractor failure during sugar cane harvesting. C_i factor is machine effective capacity in ASAE formula (Eq. 1) that is equal to multiplying $C_i E_f$ where: C_i is machine theoretical capacity and E_f is field efficiency. Based on the ASAE Standard EP496.3, field efficiency is the ratio between the

productivity of a machine under field conditions and the theoretical maximum productivity. Field efficiency accounts for failure to utilize the theoretical operating width of the machine; time lost because of operator capability, habits and operating policy; and field characteristics. Travel to and from a field, major repairs, preventive maintenance, and daily service activities are not included in field time or field efficiency. By multiplying tractor coefficient to the ASAE formula a new method was developed to segregate tractor timeliness cost from total timeliness cost of sugar cane harvesting.

In technical and economical assessment of machine, reliability is important and practical because decreasing machine

reliability can cause to a failure and delay in field operation. This delay results in some losses in yield quantity and quality named *timeliness cost*. The severance of timeliness cost sources is difficult and complicated. In this research one of these sources of timeliness of field operation was investigated. Tractor timeliness cost was estimated based on its reliability function in Debal Khazaei Agro-Industry company conditions. Timeliness cost increased whatever machine mission time increased and intensity of increase in lower mission times was lesser than upper ones. If tractor mission time (t) becomes shorter, tractor timeliness cost substantially will be lesser because in this case tractor will be serviced sooner and be given a new mission again.

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